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Investigation on the Constraint Factors in Waste Management in Owerri Imo State, Nigeria

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ABSTRACT

This research involves the investigation on the constraint factors in waste management in Owerri, Imo State. Data was collected and compiled by means of questionnaires and interviews with relevant contractors and establishment in charge of waste management in the State. Based on the result it was found that factors like vehicle capacity, settlement routes and personnel are the three major factors affecting waste management and disposal. A python algorithm was used to process the data and mathematically provide the model regarding the three factors and the number of breakdowns. With the aid of the python algorithm, a mathematical model was created and this model showed to have approximately 100% similarities with the original data collected. Furthermore, both calculated and probability/reliability test was carried out. Result showed that the waste management system in Owerri is not reliable because the probability of having a breakdown value less than or equal to 1 is about 2.63%. From the result, the following recommendation were made: proper route planning for truck sent to rural areas with bad roads; better selection of vehicle for a particular community or settlement; preparation and presentation of status report for any truck dispatched to receive waste from the community; carrying out periodic maintenance to improve the life of trucks and ensure that it runs optimally and training personnel to handle random breakdowns that can happen any time.

Key words: Waste, management, data, Owerri, model, Nigeria

1. INTRODUCTION

Solid waste can be defined an unwanted material emanating from commercial, industrial, and residential activities. It can also be an inconsequential solid material resulting from any activity or industrial methods without a present economic usefulness. However, it must be regarded as waste in order to prevent its ability to pose as a source of harm and danger to people and the environment [1-4].

As the years go by and population density intensifies, societal levels of exploitation of natural resources as well as industrial activities increase, more waste are produced thus there is need to adequately manage the waste. In the pre modern era, common waste produced are mainly ashes and human biodegradables which were released back into the ground as way of disposal

to minimize environmental impact [5-7]. There are different types of waste; the solid, liquid and gaseous waste each having different types of disposal and management technique. We equally have industrial, biological and household waste which is produced by human activities, which poses threat to human health so therefore waste management focuses on reducing the adverse effect of waste on human health, the environment and aesthetics [8-10].

The problem which necessitated this investigation includes issue surrounding indiscriminate disposal of refuse and frequent breakdown of waste disposal trucks [11]. It is no news that waste disposal trucks breakdown frequently in Nigeria, and Owerri is no exception [12]. And since it has the tendency to ascertain the efficiency and effectiveness of waste management procedures, it is important they are efficiently managed to maintain a smooth running of activities in the establishment in charge of waste management [13]. Furthermore, if they are not well managed it might lead to breakdown which will affect evacuation processes which will ultimately lead to outbreak of diseases and equally pose as source of harm and danger to the environment [14-16].

Objectives of the study is to predict the number of truck breakdowns using a multi regression model as well as consider the reliability analysis on the waste management method used in Owerri, Imo state. This will be based on waste generation and waste disposal as well as proffer solution for improvement based on the result gotten from the reliability analysis. This study will aim at assessing different facets of WMS in Owerri, Imo State Nigeria, as regards waste generation and disposal, and to consequently evaluate the risk associated with inefficient and ineffective management procedures as regards waste disposal trucks [17]. It will also be of value to the government to maintain absolute serene and clean environment, reduce environmental pollution and outbreak of diseases while also providing employment opportunities to the teeming youths [18-19]. Finally, the result of this dissertation will add something new to existing body of knowledge on the subject on current literature [20-21].

In order to combat this challenge, a copious approach must be taken so as to encourage waste minimization, application of pollution prevention methods and adequate sensitization of residence about waste management procedures and centralized waste treatment of effluents [22]. Researchers opined is to make a waste management procedure feasible, the following parameters should not be considered; frequency of collection, distance, climate and disposal route [23-25]. But distance and disposal route plays an integral part in the life span of disposal trucks in the sense that if the terrain along the route is bad it will result to more wear and tear on the trucks which will ultimately lead to breakdown [26-27]. Also frequency of collection is equally important because if waste is not being collected when due, it might lead to outbreak of diseases which of course will endanger the life of the populates [28-30]. Researcher pointed on solid waste collection is labour intensive and accounts for nearly three quarters of the total cost of solid waste management [31-33].

2. MATERIALS AND METHODS

Sources of Data

Data was collected for both primary and secondary sources. The primary data was collected by means of formal interview and questionnaires while secondary data was obtained from books, journals, annual and government reports, internet, private and organizational webpage and unpublished papers.

Method of Data Collection

Data for this research was collected through questionnaire.

Method of Data Analysis

Sample Size Determination

The sample size was calculated using Cochrane formula

$$N_o = \frac{z^2pq}{e^2} \quad (1)$$

where N_o is population sample size, z is z-score gotten from the z-table, P is estimate proportion of an attribute in a population, q is $1-p$ and e is desired level of precision. Equation (1) will be used to calculate the sample size that will represent the overall population, this may also include a 5% precision.

Regression Analysis

Irrespective of the demographic data analysis using IBM SPSS version 20 and Python Algorithm, there will also be some relativity with respect to the factors affecting waste management. The data collected will be used to do a plot that can help to develop a

model relating both dependent and independent variables. This section discusses the empirical analysis of the relationship between the factors that are suspected to affect waste management and its operation for a period of six months. Various researchers have attempted building ideal model to predict solid waste characteristics as a reliable tool and parameter. They found that relationship obtained between various parameters vary among countries. This has been attributed to variations in consumer behaviour and lifestyles. Normally, waste is a function of consumers' consumption and activities. The relationship between waste and consumption activities may be expressed as proportion in which waste generated is directly proportional to waste consumption [30].

$$W \alpha C \tag{2}$$

$$W = \beta C \tag{3}$$

where W is vector component of solid waste, β is vector coefficients relating to the types, quantities and factors relating to waste management of solid waste with consumption activity, C is vector representing consumption activities.

Linear Regression

The expression for linear regression is shown in equation (4), we have

$$y_m = B_0 + B_1(x) \tag{4}$$

where y_m is the estimated value for the dependent factors (modelled number of breakdown), B_0 is intercept on the y-axis of the graph, B_1 is the slope of the estimated line, x is the independent variable or factor

$$B_1 = \frac{n\sum xy - (\sum x \sum y)}{(n \times \sum(x^2)) - (\sum x)^2} \tag{5}$$

$$B_0 = \frac{\sum y - (b_1 \times \sum x)}{n} \tag{6}$$

However, for a multiple variable regression with more than one factor equation (4) can be written as follows

Multiple Regression

The equation for multiple regression with more than one factor can be expressed from equation (7) – (12) , we have.

$$y_m = B_0 + B_1(x_1) + B_2(x_2) + B_3(x_3) + \cdots + B_n(x_x) \tag{7}$$

Putting the factors x_1, x_2, x_3 into equation (7), we have

$$B_0\text{n} + B_1\sum x_1 + B_2\sum x_2 + B_3\sum x_3 = \sum y_1 \tag{8}$$
$$B_0\sum x_1 + B_1\sum x_1^2 + B_2\sum x_2x_1 + B_3\sum x_3x_1 = \sum y_1x_1 \tag{9}$$
$$B_0\sum x_2 + B_1\sum x_2^2 + B_2\sum x_2x_1 + B_3\sum x_3x_2 = \sum y_1x_2 \tag{10}$$
$$B_0\sum x_3 + B_1\sum x_1x_3 + B_2\sum x_2x_3 + B_3\sum x_3^2 = \sum y_1x_3 \tag{11}$$

where $B_{0,1,2,3,n}$ are different independent variables, n is Number of dependent variables.

Applying matrix triangulation method to equation (8) – (11), it becomes

$$\begin{bmatrix} n & \sum x_1 & \sum x_2 & \sum x_3 \\ \sum x_1 & \sum x_1^2 & \sum x_2x_1 & \sum x_3x_1 \\ \sum x_2 & \sum x_2^2 & \sum x_2x_1 & \sum x_3x_2 \\ \sum x_3 & \sum x_1x_3 & \sum x_2x_3 & \sum x_3^2 \end{bmatrix} \begin{bmatrix} B_0 \\ B_1 \\ B_2 \\ B_3 \end{bmatrix} = \begin{bmatrix} \sum y_1 \\ \sum y_1x_1 \\ \sum y_1x_2 \\ \sum y_1x_3 \end{bmatrix} \tag{12}$$

Equation (12) was solved using python algorithm written for this research in Appendix A.

Based on the value for y obtained the R^2 value can be calculated using equation (13), we have.

$$R^2 = \frac{\sum_{i=1} (\hat{y}_i - \bar{y})}{\sum_{i=1} (y_i - \bar{y})} \qquad (13)$$

where ŷ is the value obtained from the regression analysis, $\bar{y}$ is the mean of both the original data and the model data (the model mean is equal to the original data mean), y is the value for the original data.

The factors affecting waste management can be broken down as shown in Figure 1.

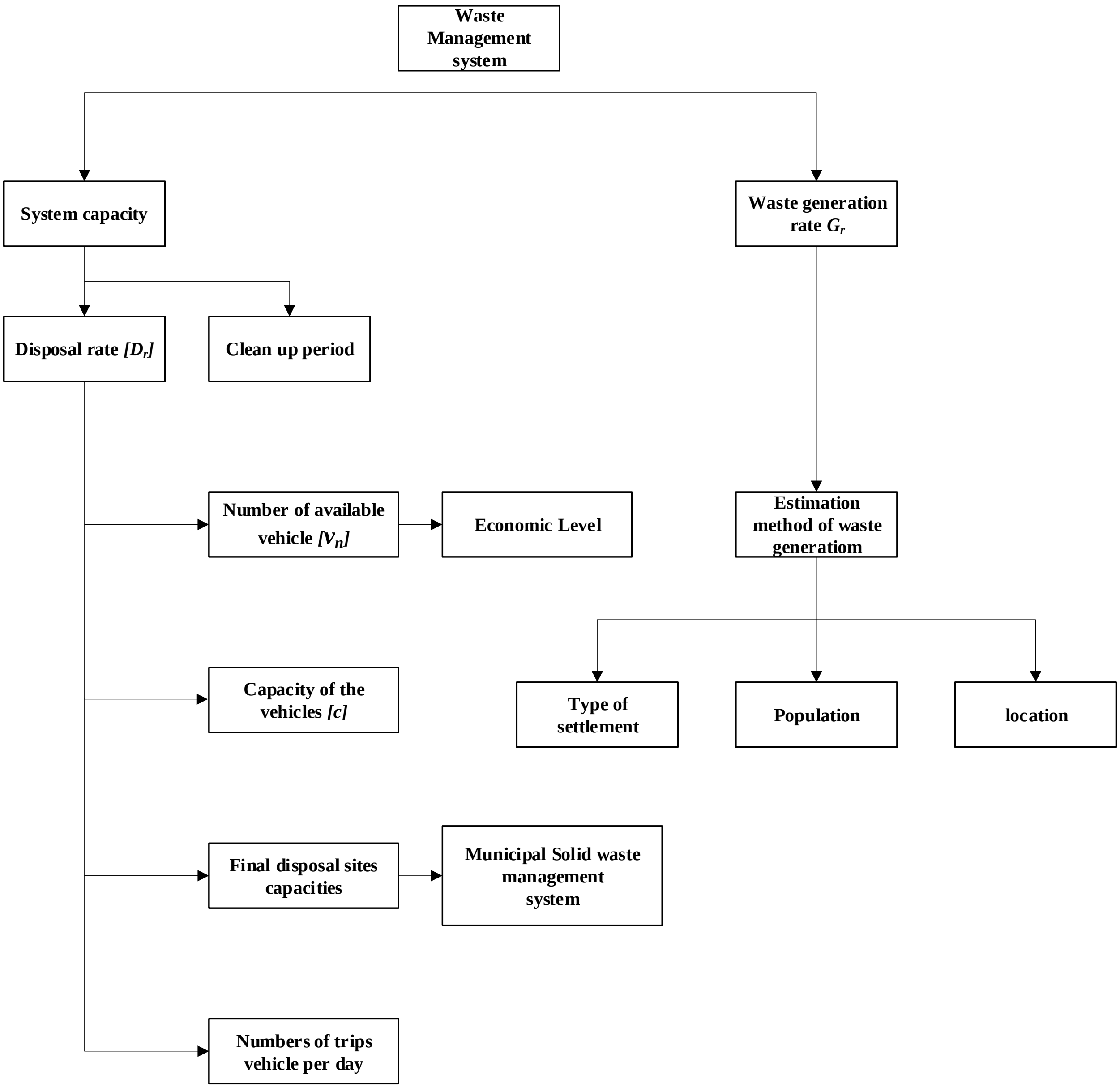

Figure 1: Factors Affecting Solid Waste Disposal [12], [31]

Normal Distribution

The normal distribution is a type of distribution in which the mean on the x-axis is the highest point on the y-axis. It is a symmetrical bell shaped curve. It deviates outwardly from both sides of the mean in the middle (mean is at 50%) following the normal 65%, 95% and 99.7% rule as shown in Figure 2.

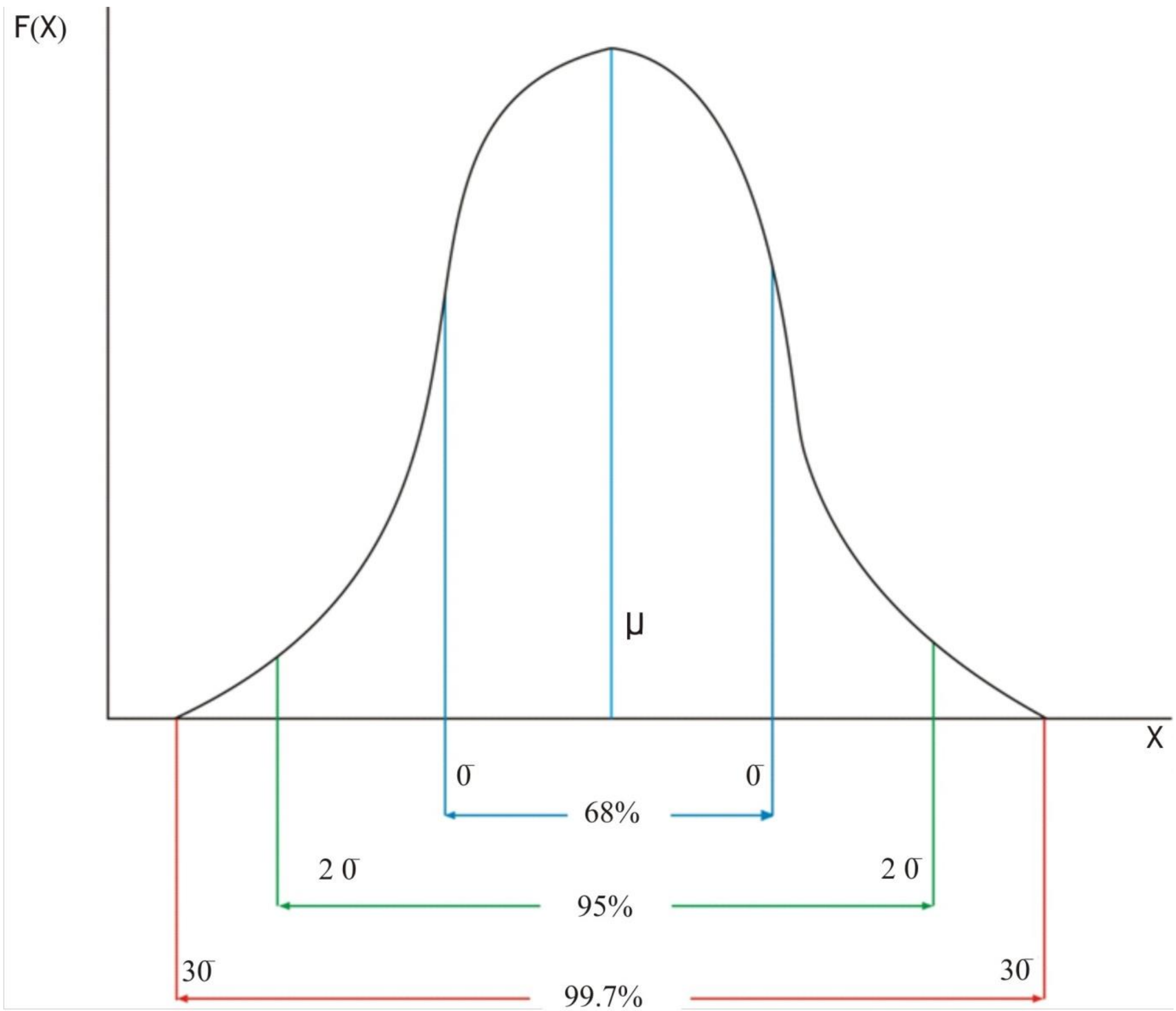

Figure 2: Example of a Normal Distribution [13]

The Probability Density Function (PDF) is written as:

$$F(x) = \frac{1}{\sqrt{2\pi\sigma^2}} e^{-\frac{(x-\mu)^2}{2\sigma^2}} \tag{14}$$

where F(x) is Probability density function, σ is variance of the sample data, μ is mean of the sample data, x is arbitrary value in a sample data

The integral of equation (14) from zero to infinity gives the Cumulative Distribution Function (CDF) which equates to 1, representing the probability that P(x<∞) =1 (100%). This shown as follows:

$$P_f = P(X < \infty) = \int_0^{\infty} F(x)dx \tag{15}$$

$$= \frac{1}{\sqrt{2\pi\sigma^2}} \int_0^{\infty} e^{-\frac{(x-\mu)^2}{2\sigma^2}} dx \qquad (16)$$

Let, $$u = \frac{x-\mu}{\sqrt{2}\sigma}$$

Equation (16) becomes:

$$= \frac{1}{\sqrt{2\pi\sigma^2}} \int_0^{\infty} e^{-u^2} dx \qquad (17)$$

Integrating the Gaussian integral in equation (17), we have

$$P(X < \infty) = \frac{1}{\sqrt{2\pi\sigma^2}} \times \sqrt{2\pi\sigma^2} = 1 \qquad (18)$$

$$\therefore P(X < \infty) = 1 \qquad (19)$$

Equation (19) shows the overall probability of X to be less than ∞ is 1. However, the general function for the CDF of *[x]* less than any value *[a]* is given as:

$$P(x < a) = \frac{1}{2} erf\left(\frac{\sqrt{2}(-\mu + x)}{2\sigma}\right) + 0.5 \qquad (20)$$

Addition of 0.5 is to offset the y axis to start from 0 and end in 1 instead of -0.5 to 0.5

Erf is an error function obtained when integrating the Gaussian integral in the equation (14). This kind of integration is best done with the aid of computer software. In this research python is used to perform complex mathematical operations using python sympy library.

Generation of Normal Distribution Sample Data

The table for the normal distribution is formed with the following parameters:

s_i = Sample start value, d_i = Density of sample, the lesser the value the more accurate the analysis becomes, $\bar{x}$ = Mean value and σ = Standard deviation

Steps for generating the sample in any program can follow the algorithm below:

i. If σ (Standard deviation) is not known, then σ can be gotten using

$$\sigma = \frac{0.68}{2} \times \bar{x} \qquad (21)$$

ii. The number of samples to be generated is derived as follows:

$$\text{No of samples} = \frac{S_i}{d_i} \times 2 \qquad (22)$$

iii. Generate density values that starts from S_i to $-S_i$ The density values follow an arithmetic progression with a difference equal to di following the sequence is shown in equation (23) , we have.

$$\{S_i, S_i - d_i, S_i - 2d_i, \dots, S_i - (n-1)d, \dots, -S_i\} \qquad (23)$$

where n is n^{th} number of Terms

iv. Generate x-values for the normal distribution function equation (16) and (21) as follows:

The first term x_1 is defined as:

$$x_1 = \bar{x} - (\sigma \times s_i) \qquad (24)$$

The following terms follows the sequence thus.

$$\{x_i, x_i + (\sigma \times s_i), \ldots, x_{n-1} + (\sigma \times s_i)\} \qquad (25)$$

v. Generate the normal distribution values, F(x) and the cumulative distribution P (x < a) with equation (14) and (20)

vi. Tabulation of the results is done using the format in Table 1

Table 1: Distribution Table Format

S/N	si	X	F(x)	P(x<a)
Index[i]	$\left\{\begin{matrix} s_i, s_i - d_i, s_i - 2d_i, \cdots \\ \cdots, s_i - (n-1)d, \cdots \\ \cdots, -s \end{matrix}\right\}$	$\left\{\begin{matrix} x_1, x_1 + (\sigma \times s_i), \cdots \\ \cdots, x_{n-1} + (\sigma \times s_i) \end{matrix}\right\}$ where: $x_1 = \bar{x} - (\sigma \times s_i)$	Use equation	Use equation

Reliability in Waste Management

Reliability method was used to calculate the reliability of waste management by relating the waste generation to the waste disposal of a waste management system. However, in this work reliability of the waste management system will be related to the number of breakdowns experience within a period of six months. Based on how complex the waste management system is, there should be a maximum allowable number of breakdowns b_{max} experienced per day. From equation (7), y_m represents the modelled number of breakdowns, therefore, it must be less or equal to the maximum allowable number of breakdowns b_{max}. For a waste management system to be 100% reliable, $y_m \leq b_{max}$. Therefore, the reliability of the system is the probability that the modelled number of breakdowns y_m is less than or equal to the maximum allowable number of breakdowns b_{max}. This can be expressed as (Cheng et al, 2018)

$$P_f = P(Z \leq 0) \qquad (26)$$

$$Z = y_m - b_{max} \qquad (27)$$

where P_f is Probability density function, y_m is modelled number of breakdowns, b_{max} is maximum allowable number of breakdowns, Z is a function relating the relationship between waste disposal and generation.

However, reliability and unreliability analysis was estimated per month for six months for both Urban and Rural settlement using simple reliability concept equation as follows

$$X_0 = X_S + X_F \qquad (28)$$

where X_O is the number of trucks, X_S is the number of trucks in operation and X_F is the number of trucks not in operation.

$$\text{Unreliability} = \frac{X_F}{X_0} \qquad (29)$$

$$\text{Reliability} = \frac{X_S}{X_0} \qquad (30)$$

$$X_S = X_0 - X_F \qquad (31)$$

$$R = 1 - \frac{X_F}{X_O} \qquad (32)$$

$$R = 1 - U(R) \qquad (33)$$

$$PDF = \frac{dR}{dt} \qquad (34)$$

$$R\ (t) = \frac{X_{F(t)}}{X_0} = \int_0^t f(\tau) d\tau \qquad (35)$$

3. RESULTS AND DISCUSSION

Regression Analysis Results

The input for the regression analysis was from the demographic data collected from different waste disposal companies, interviews with relevant contractors and questionnaires with residence of Owerri. These data contain three variables that are constraint factors that affects the number of breakdowns experienced by waste disposal trucks. These factors are as follows: Truck capacity, type of settlement and number of personnel assigned to a truck

Since the number of factors considered are more than one, it is very imperative to use a computer software to resolve the model representing the relationship of all the factors in the system. It takes in a table containing all the factors affecting the number of breakdowns recorded. The python algorithm makes use of equations (7) to (12). However, in order to know the extent to which every factor affects the number of breakdown experienced, the statistical correlation of every factor is first calculated and tabulated before the python algorithm begins to run.

Table 2: Factor Correlations and Effects

`Factors	Rural	Urban	Truck Capacity	No. of personals	Breakdowns
rural	1	-1	-0.105	0.021	0.684
Urban	-1	1	0.105	-0.021	-0.684
Truck capacity	-0.105	0.105	1	-0.005	-0.596
No. of personals	0.021	-0.021	-0.005	1	0.509
Breakdowns	0.684	-0.684	-0.596	0.509	1

Based on the data collected and analysed, Table 1 shows how every factor influences the number of breakdowns recorded. The effects of all the factors on each other was also derived in Table 2. While Figure 3, shows the graphical illustration of the effects of rural settlements, urban settlements, truck capacity and personnel on the number of breakdowns recorded.

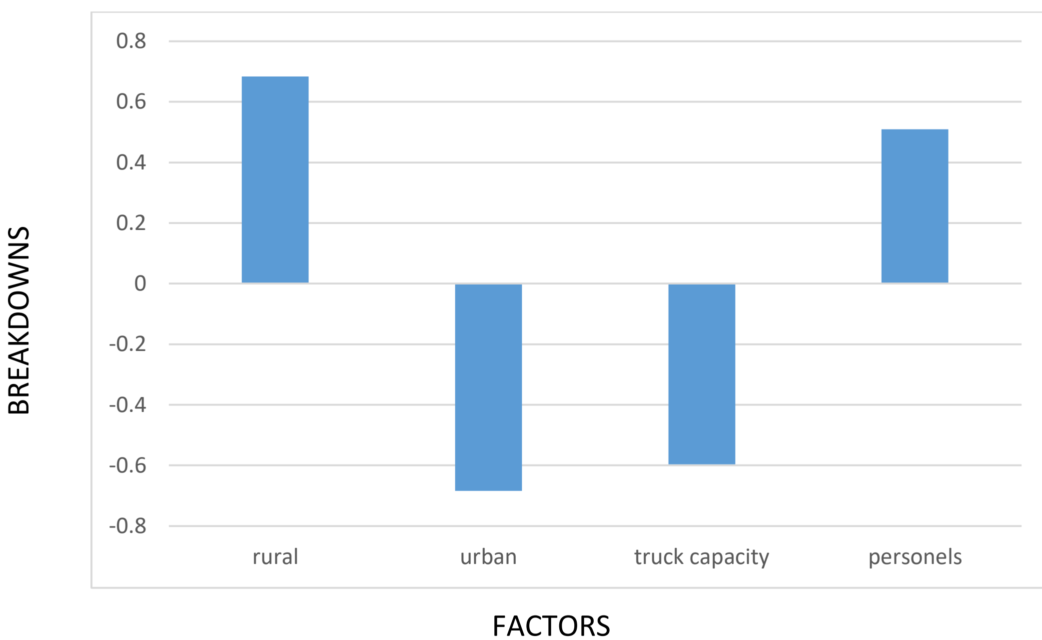

Figure 3: Correlation of Factors

According to Figure 3 from the data analysed, the following effects can be summarized.

Effects of Rural Settlement

Rural settlement has a direct impact of 68.4% (0.684) on the number of breakdowns reported. This means that the more the rural area a disposal truck passes through, the more the number of breakdowns it may experience. This can be linked to bad road and poor accessibility often associated with rural settlements or areas.

Effects of Urban Settlement

Urban settlement has an inverse effect on the number of breakdowns reported. This means that the more an urban area is developed the lesser the number of breakdowns. However, urban and rural settlement has equal but opposite effects on the number of breakdowns recorded. Referring to Table 4.1, it is shown that the effect of rural settlement on the number of breakdowns recorded is 0.684. Whereas, the effect of urban settlement is a negative value (-0.684) with the same absolute value $abs(-0.684) = abs(0.684)$). This also confirms that a settlement can be one of the two types mentioned above.

Effects of Truck Capacity

The capacity of any truck considered can have an indirect effect of 59.6% on the number of breakdowns reported. This means that the more the capacity the less the breakdowns reported. This was made clear with a reasonable example of how if a truck has a sufficient capacity to handle the waste generated by the community, it will be very impossible to overload the truck beyond its carrying capacity, However, if the truck is of insufficient capacity it can get overloaded and then increase the chance of being broken down.

Effects of Number of Personnel

The number of personnel has a direct effect on the number of breakdowns recorded. This is because based on the data analysed more breakdowns was associated to a greater number of personnel's accompanying a disposal truck. Reasons for this is unknown, but it may be due the overloading as per the added number of weights caused by the extra numbers of personnel's. In a nutshell, rural settlement, urban settlement, truck capacity and number of personals has 0.684, -0.684, -0.596 and 0.509 effects on the number of breakdowns.

Mathematical Model Result

The mathematical model was derive using the python algorithm, this algorithm was able to prepare the data collected. The algorithm categorises the categorical columns like the settlement column. This is to be able to analyse the correlation of the two categories individually. Later on, in the algorithm 50% of the data collected was then used to obtain the mathematical model relating to the waste generation and disposal. Furthermore, multiple linear regression following equations (7) to (12) was then used to obtain the model relating all the factors listed above to truck breakdowns.

Selection of Sample Size

The sample size needed was derived using equation (1) firstly, a confidence level of 95% was selected because it was needed that the sample correlates with the original population by 95%. After the selection of confidence level, the z-score was obtained using the normal distribution graph in figure 4.

From Figure 4, a 95% confidence level is between 2σ to 2σ, where the first 2σ on the left represents the negative z-score (-z) and the 2σ on the right represents the positive z-score (z). This is depicted in Figure 4 in which the confidence level of 95% (0.95) falls between -z and z. In a normal distribution the total area under the curve is always equal to 1. Therefore, 0.95 was subtracted from 1 to give 0.05, which was then divided by 2 to get 0.025 for the opposite sides of the normal distribution.

In a normal distribution, the area under the curve (which can also represent the probability value, p-value) is taken towards the left of the curve. In that regard, the area under the curve from z to -∞ is equal to $0.95 + 0.025 = 0.975$. Furthermore, the z-score is obtained by referring to the Z-normal distribution table as shown in Appendix E. The probability value of 0.9750 is first located in the table, then the z-score of one decimal place will be located on the extreme left as 1.9 while the z-score of two decimal place will equally be located on the top as 0.06. Finally, these two values are added together to obtain the final z-score for 0.9750 as $1.90 + 0.06 = 1.96$. Therefore, the z-score for the sample size is 1.96.for the precision level $e = 0.05$ and similar analysis selected $pq = 0.395$.

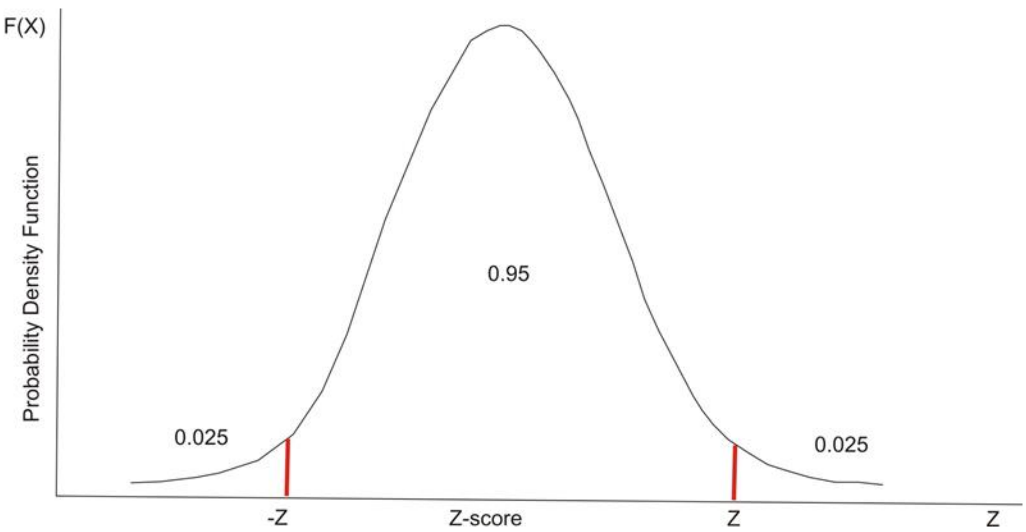

Figure 4: Z-Score Calculation [14]

The required sample size was derived as follows;

$$N_0 = \frac{1.96^2 \times 0.395}{0.05^2} \cong 600$$

According to the calculations above, the sample size N_0 is 600. Therefore, the data was selected using random sampling to get up to 600 samples.

Separating Categorical Factors

Referring to the sampled data in settlements is an example of a categorical data with two options, urban and rural. In order to develop a mathematical model these data have to be converted to a normal data with numerical values. For instance, after separating the settlement data, two columns were created in-place of the original settlement data. In which, rural is given a value 1 for each time it is a rural settlement whereas urban is allocated a value 0. Relatively, if the settlement is urban, urban is given a value 1 whereas rural is given a value 0. The data of the sample was separated using an algorithm written in python. A sample of the separated categorical data is shown in Table 3.

Table 3: Separated Categorical Data from Python Algorithm

S/No	Rural	Urban	Truck Capacity(kg)	Personals	Breakdowns
1	1	0	1000	4	7
2	0	1	3000	6	4
3	0	1	2000	6	5
4	0	1	2000	4	3
5	0	1	4000	6	3
6	1	0	1000	4	7
7	0	1	2000	8	6
8	0	1	4000	6	3
9	1	0	3000	4	5
10	1	0	3000	5	6
11	0	1	1000	5	5
12	1	0	2000	4	6

S/No	Rural	Urban	Truck Capacity(kg)	Personals	Breakdowns
13	0	1	2000	4	3
14	1	0	1000	4	7
15	1	0	1000	6	9
16	1	0	1000	5	8
17	0	1	2000	5	4
18	1	0	3000	8	8
19	1	0	1000	5	8
20	0	1	1000	6	6

An instance of the separated categorical data is given in Table 2, in which wherever a settlement is rural or urban 1 is allocated to that data point. Also, wherever it is not urban or ruler, the value 0 is allocated to that data point. This is done for all data points in the original sample data collected.

Resolving the Mathematical Model

After the categorical factors has been separated, the next step was to use the python algorithm that follows equations (7) to (12). The python algorithm was written to be able to handle categorical data wherever columns are found in sample data. Based on the data collected, the following multi-variable mathematical model was produced as follows:

$$y = 1.377x_{00} - 1.377x_{01} - 1.102 \times 10^{-3}x_1 + 7.438 \times 10^{-1}x_2 + 3.864 \qquad (36)$$

In the model in equation (36), y is the number of breakdowns, x_{00} is the value for the settlement if it is a rural settlement, x_{01} is the value for the settlement if it is an urban settlement, x_1 is the capacity of the truck sent to a particular settlement, and x_2 is the number of personals attached to a truck sent to the settlement. The last number 3.864 is the intercept on the y axis for the model. This value remains constant for all the factor values.

Normal Distribution Reliability Result

The result was created in an excel worksheet to summarise the model data result, since the model result is approximately similar to the original data by 100%. Therefore, the mathematical model can be used to predict breakdown values for any conditions based on the initial factors in this research. The statistical table that gives the probabilistic value for any number of breakdowns y in the system.

Based on the current system, statistically the probability of having a breakdown less than 1, $P(y< 1) = 0.0263$ [2.63%] from the reliability graph on Figure 4. Since the probability of having at most 1 breakdown is 2.63%, it can be concluded that the management system in Owerri is unreliable and needs further development. Figure 5, illustrates the reliability of the system.

Reliability for Urban Dwellers

The result was created on excel spread sheet to summarise the reliability and unreliability of both urban and rural settlements. However, the manner of the decline in reliability rate is illustrated in Figure.6 it is clear that the rate of reliability decreases with an increase in time. This is an indication that the waste management parameters deteriorate or wear-out with time. As the failure rate increases the reliability of the component decreases. It also confirms that reliability decreases with time this is due to the ageing of the components, over loading of the Truck and increase in number of personal. From Figure 6 shows a steady decline in the reliability of the system over the period with root mean square value of 0.9799 and is in agreement with other researchers. In addition to the aging of the components there is an indication of shortage of experience workers, which contributed to high failure of the machine leading to a declined in reliability down the period. Also the random failure mode of truck could be attributed to the variation of process parameters.

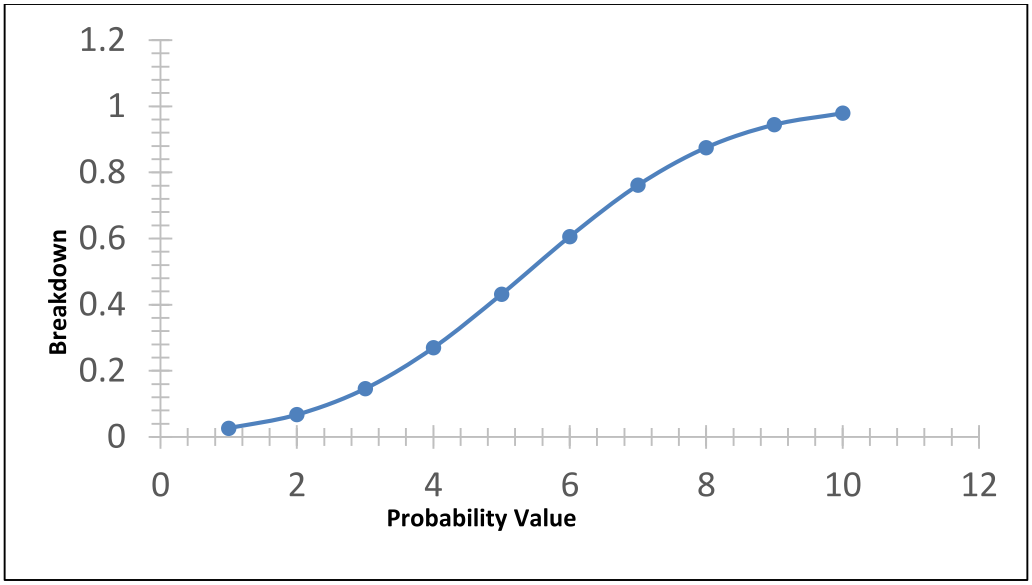

Figure 5: Reliability of the system

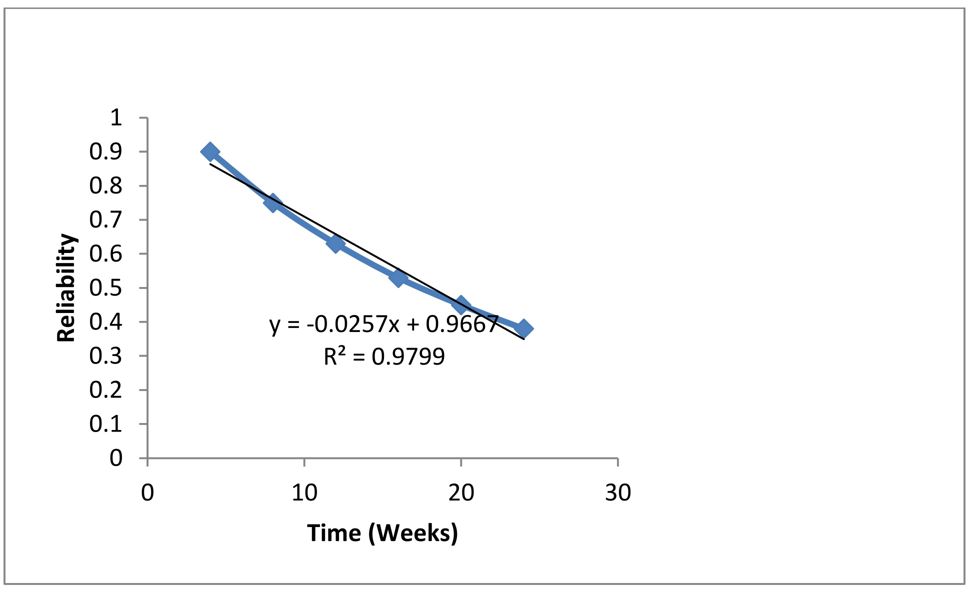

Figure 6: Reliability of waste management system against operating time (Weeks) for Urban Dwellers

Unreliability for Urban Dwellers

Figure 7 illustrates the rate of unreliability of the waste management system in urban area with time. It is observed that the rate of unreliability of the system is a reverse of the reliability as unreliability increases with time. This shows that the system parameters deteriorate or wear-out with time. As the components of the waste management system keep failing, the rate of unreliability of the system increases. The unreliability is seen as the integral of the failure. Is also a clear indication that unreliability increases with time this is due to the ageing of the components. Figure 7 shows that there has been a steady increase in the unreliability of the system over the period with the root mean square value of 0.9799.

And Figure 8 shows the point where reliability and unreliability met. It is called a point of availability which signifies that at every point in time in the urban areas, there must be available truck to dispose waste from the dumpsite to the final disposal point.

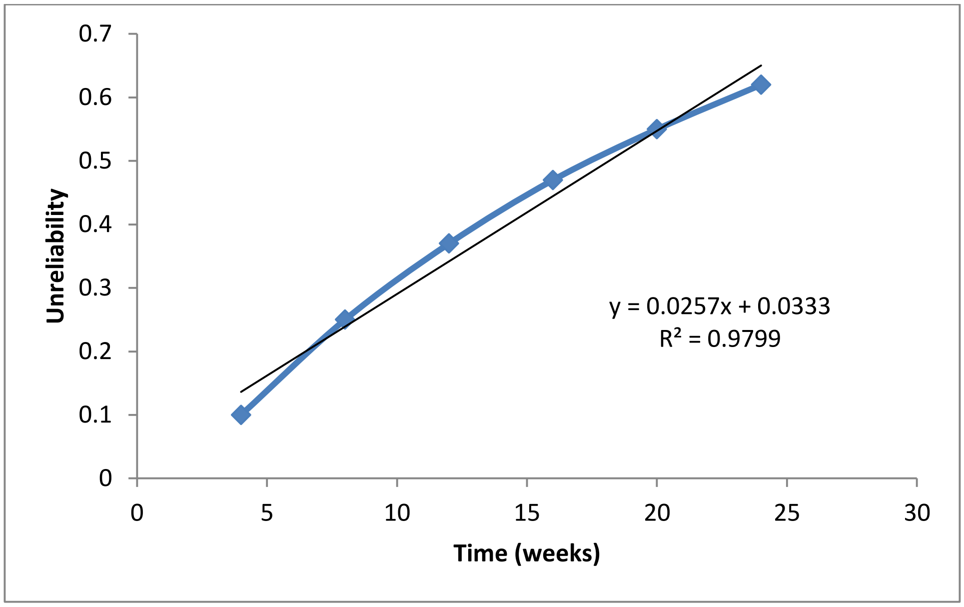

Figure 7: Unreliability of waste management system against operating time (Weeks) for Urban Dwellers

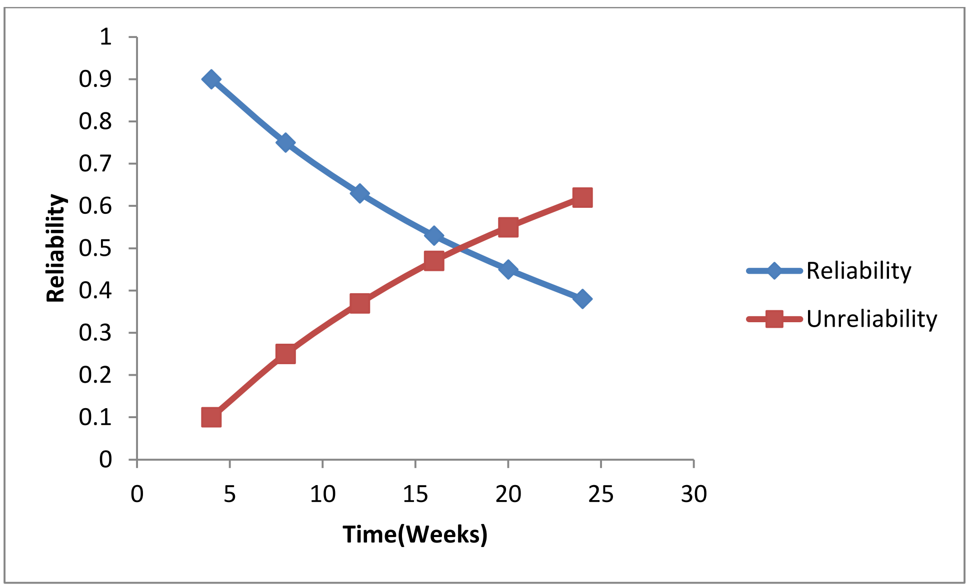

Figure 8: Graph of Reliability and Unreliability against Time of Refuse Disposal per week for Urban Dwellers

Reliability for Rural Dwellers

Figure 9 illustrates a cumulative distribution function. However, the reliability as a result of failure. From the Figure 10 it is observed that the rate of reliability decreases with an increase in time. This is an indication that the waste management parameters deteriorate or wear-out with time. As the failure rate increases the reliability of the component decreases. It also confirms that reliability decreases with time this is due to the ageing of the components over loading of the Truck and increase in number of personal and poor road network. Figure 10 shows a steady decline in the reliability of the system over the period with root mean square value of 0.9966 and is in agreement with other researchers. In addition to the aging of the components there is an indication of shortage of experience workers, which contributed to high failure of the machine leading to a declined in reliability down the period. Also the random failure mode of truck could be attributed to the variation of process parameters.

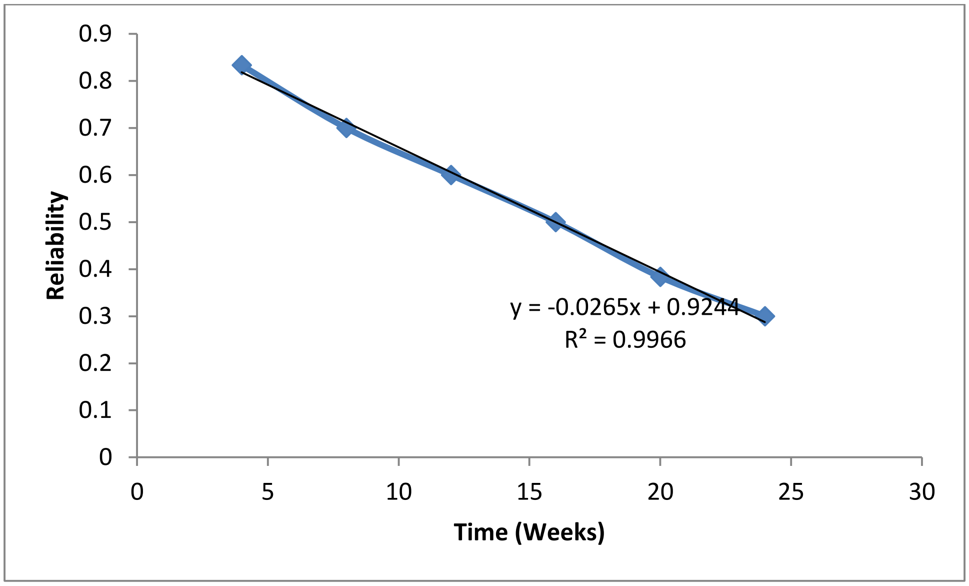

Figure 9: Reliability of waste management system against operating time (Weeks) for Rural Dwellers

Unreliability for Rural Dwellers

Figure 10 illustrates the rate of unreliability of the waste management system in rural area with time. It is observed that the rate of failure increases with time, thus is an indication that many of the function parameters or products were wearing out or deteriorating with time. Thus unreliability of the system is a reverse of the reliability as unreliability increases with time. As the components of the waste management system keep failing, the rate of unreliability of the system increases. The unreliability is seen as the commutative distribution function of the failure. It also a clear indication that unreliability increases with time, this is due to the ageing of the components. Figure 10 shows that there has been a steady increase in the unreliability of the system over the period with the root mean square value of 0.9966. And Figure 11 shows the point where reliability and unreliability met. It is called a point of availability which means that at every point in time in the rural areas, there must be available truck to dispose waste from the dumpsite to the final disposal point.

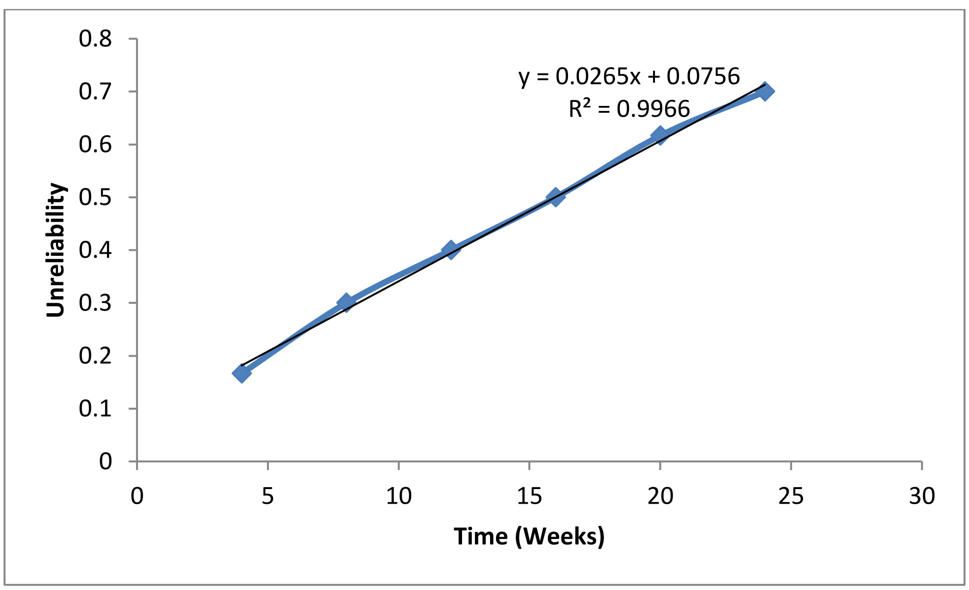

Figure 10: Unreliability of waste management system against operating time (Weeks) for Rural Dwellers

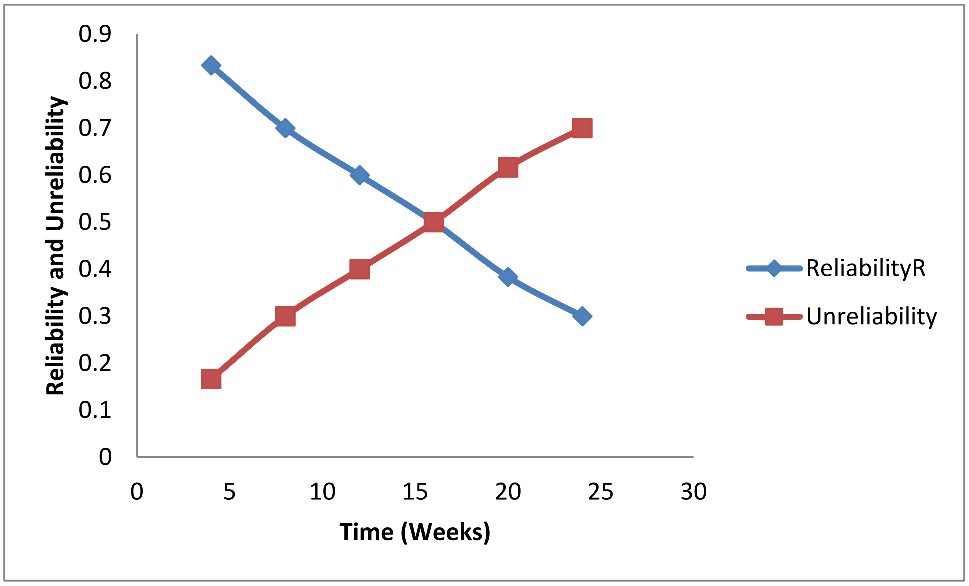

Figure 11: Graph of Reliability and Unreliability against Time of Refuse Disposal per week for Rural Dwellers

4. CONCLUSION

Based on this research and the data analysed pertaining waste disposal and truck breakdown in Owerri the following conclusion was drawn up.

i. The main constrain factors which causes truck breakdown during waste disposal process may depend on type of settlement the truck is passing through, the number or types of personals, and the weight of waste being disposed.
ii. A reliability analysis was carried on the data involving waste management in Owerri and frequency of breakdown experienced. The result shows that the current system is not very reliable, since the probability of having at most 1 breakdown is 2.63% also the calculated reliability analysis shows that there is need for improvement in the system.
iii. To improve this condition, the following must be done, improve the method of vehicle selection, improve personnel's to be able to handle problems emanating during waste disposal. Proper route planning to avoid bad roads in most rural areas.

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Conflict of Interest

The author declares that there are no conflicts of interests.

Data and materials availability

All data associated with this study are present in the paper.

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